8. Rivers

Rivers are responsible for most sediment transport from mountains to lowlands and the oceans. They do the most to even out the topography that tectonic processes create. Rivers consist of channel, bank and overbank or floodplain deposits. Most of the sediment and many river characteristics are controlled by the highest common flow speeds.

1. Straight (rare, except for ones humans have modified)
2. Braided (many branches within a channel)
3. Meandering (high sinuosity)
4. Anastomosing (rivers with branching and merging channels)

The form of the river is controlled by the gradient of the river bed (steep = braided, gently dipping = meandering), local vegetation that stabilizes banks and limits the number of channels, sediment grain size, particularly the ratio of suspended versus bedload sediment, and sediment volume. A high bedload gives rise to abundant bars, which promotes formation of braided rivers.

Braided rivers develop when the proportion of bedload sediment is high, which produces abundant bedforms and promotes the development of bars, and thus, the braided character of the river. The sediment is commonly coarse, which requires fast flow and steep gradients for the sediment to be transported. Much of the geometry of braided rivers is shaped by the highest flows, e.g. spring floods, when the bars are covered in water. Many braided rivers have exposed bar tops for much of the year.

Flow speeds and transport capacity vary dramatically within a braided river. Friction with the riverbed tends to slow down the flow, particularly where the flow is shallow. Thus, the Reynolds number in shallow areas is relatively low (but still high
enough that the flow is turbulent) and the transport capacity is low. In contrast, the transport capacity and Reynolds number are much higher in the deeper middles of channels in the river. Thus, the coarsest sediment is transported here, whereas finer sediment gets deposited in shallow areas. Also, bars block the flow on the upstream sides, and like dunes, the upstream sides tend to erode. Areas of low flow and eddies form on the downstream sides of bars, and they are usually sites of net deposition. Thus, bars migrate downstream through time. If we summarize the processes:

**Sediment Transport**
1. The coarsest sediment is only transported in the middle of the flow where the Reynolds number is highest. (All grain sizes that can be moved are transported where Re is high.)
2. Bars are eroded upstream where the bars deflect the flow. Sediment is deposited on downstream side of bars and some on the flanks of bars where flow is slower, particularly on the insides of bends.
3. Secondary bedforms, i.e. planar beds, dunes, and ripples, form as a result of sediment transport on the bars and in the channels.

**Sedimentary Structures**
1. Trough x-bedding in channels, due to the migration of irregular dunes
2. Coarsest sediment may be lower flat laminated if flow speeds are not fast enough to form coarse grained dunes
3. Sediment on the edges of bars fines upward because the flow is shallower and slower, e.g. has a lower Reynolds number. Sedimentary structures can include anything from upper planar to ripple laminations.

**Braided River Facies**
Channels migrate back and forth leaving a sheet of sand with abundant cross stratification. These sheets of sand tend to fine upward because the channels migrate due to bar migration, and sediment is finer grained higher up on the bars. General characteristics of braided river deposits include:
1. Scoured surface at the base of a channel
2. Gravel lag at base of channel
3. Trough x-bedded sands deposited just off the center of channels
4. Occasional tabular x-stratification from migrating bars
5. Sand deposited at slower speeds (ripple cross lamination possible)
6. Overbank deposits from floods mostly composed of sand and silt, with some mud

The large scale geometry of the deposits includes sheets of sand with various grain sizes representing bar migration, with sand sheets separated by floodplain deposits.

Example of a braided river in Alaska: http://g.co/maps/wrk9n It is cutting through glacial moraines deposited as a glacier retreated up the valley. Follow the river downstream (to the north and east) to http://g.co/maps/q5kq7. How does the channel
geometry change?

Meandering rivers have a low gradient and thus slower flow, and usually have a high proportion of suspended sediment relative to the amount of bedload. A meandering river channel has curves that meander back and forth on a gently sloping floodplain. The flow speed in the channel varies with the geometry of the meanders. Water has to travel farther on the outside of bends than on the insides of bends, so flow speeds are higher on the outsides of bends. We know from the relationships between Reynolds number and bed shear stress that higher flow speeds mean that more and coarser sediment can be transported at higher flow speeds. Thus, we can predict that:

1. There is more erosion on the outsides of bends.
2. The sediment moving near the outsides of bends and in the deepest parts of the channel should include the coarsest sediment available.
3. Sediment will accumulate on the insides of bends, and this sediment will be finer grained.

If we look at a channel in cross section, it is asymmetric, representing the sites of erosion and deposition. Variation in flow speed also produce different sedimentary structures. Upper planar lamination and dune cross stratification are common where the Reynolds number (Re) is highest, and ripple cross lamination is common where Re is lower.

The main parts of the channel include eroding bank, the thalweg (the deepest point of the flow) and the point bar (on the inside of the bend where most sediment is accumulating). As the channel migrates due to erosion and deposition, a distinctive suite of sedimentary structures accumulate. The deepest part is coarser and has upper planar lamination or dune cross stratification. This is overlain by finer sediment with current ripple lamination.

As meandering rivers migrate, the meanders tend to increase in size. Eventually, the channel forms almost a circle, and the meander gets cut off, often during a flood. This straightens the channel temporarily and produces an ox bow lake in the abandoned meander. The lake accumulates mud and organic matter since the flow speed is close to zero.

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**Levees and Floodplains**

When a river floods, it goes from a confined flow in the channel, which is very fast, to a widespread flow across the floodplain. The flow slows down very quickly and the water becomes shallower, both of which cause a decrease in Reynolds number. Thus, the water can not transport as much sediment on the floodplain as it does in the channel. Thus, finer sands that may be in suspension during a flood are transported as bedload or rapidly deposited once the river overflows its banks. This sediment deposition produces levees. The finer silts and especially clays remain in suspension much longer and settle out on the floodplain as the flood waters dry up.

Over time, the levees build up and provide a higher bank for the channel than the level of the floodplain. Thus, the channel bottom can aggrade (fill in) until the bottom of the channel is as high or higher than the floodplain. When the next flood comes along, the river avulses and does not go back into its old channel which is higher than a new one on the floodplain. This results in the downstream part of the channel being completely abandoned.
Meandering River Facies
Meandering rivers produce suites of facies that vary depending on the subenvironment. Channel facies different from floodplain and ox bow lake facies because the flow characteristics and sediment supplies are different.

Channel Facies
1. Scoured base of flow
2. Lag deposit with mud rip-up clasts and the coarsest grains being transported by the flow
3. Fining upward sands with trough cross stratification
4. Rippled sands
5. Sigmoidal cross stratification from migrating point bars

Floodplain Facies
1. Fine sand with climbing ripples near channels
2. Mudstone/shale with mud cracks
3. Soils
4. Root casts

Ox Bow Lake Facies
1. Mudstone/shale without mud cracks (unless the lake dries out)
2. Organic-rich deposits, including coal
3. Anoxic water indicators (especially in fossils and absence of trace fossils)

Braided river deposits are commonly coarser grained
2. Meandering rivers contain abundant suspended sediment, which is deposited in ox bow lakes and on floodplains.
3. Floodplain deposits are better developed and finer grained in meandering river systems.
4. Bar migration is much more regular in direction in meandering rivers because there is a well defined, single thalweg towards which the bars migrate. In contrast, braided river bar migration occurs in multiple directions at the same time. Thus, meandering rivers produce a more regular geometry of tabular cross bedding, when preserved.

1. On a large scale, river deposits consist of sheets and lenses of sand deposited in channels associated with flat laminated shales and silts with rare rippled sand beds deposited on floodplains.
2. Fining upward sequences of beds in the sands with sedimentary structures that indicate decreasing flow speeds.
3. Abundant cross stratification in well sorted sands, particularly trough cross stratification.
4. Cut banks at the edges of channels - these are good indicators of a migrating river channel, but can be hard to see in outcrop since they are rarely preserved.
5. Soil development in floodplain deposits, with root casts common if the rocks are Devonian or younger (and on Earth).

Look at pictures of fluvial rocks at http://mygeologypage.ucdavis.edu/sum...s/Fluvial.html